Predictive Science Academic Alliance Program (PSAAP)

The slides that follow were presented at the PSAAP Bidder's Meeting May 16-17, 2006 and represent the ASC Trilab authors and interests as presented in the associated White Paper for this subject area.

SAND2006-3009C

Radiation Effects

Len Lorence
Sandia National Laboratories
ljloren@sandia.gov

NNSA Predictive Science Academic Alliance Program Bidder's Meeting
Dallas Fort Worth Airport, TX
May 15-17, 2006

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company,
for the United States Department of Energy's National Nuclear Security Administration
under contract DE-AC04-94AL85000.

Outline

- Review of radiation environments and effects
- Electrical effects
- Particle radiation transport
- Material effects
- Radiation effects associated with new technology (e.g. MEMS)

Nuclear weapons are designed to survive exposure to radiation.

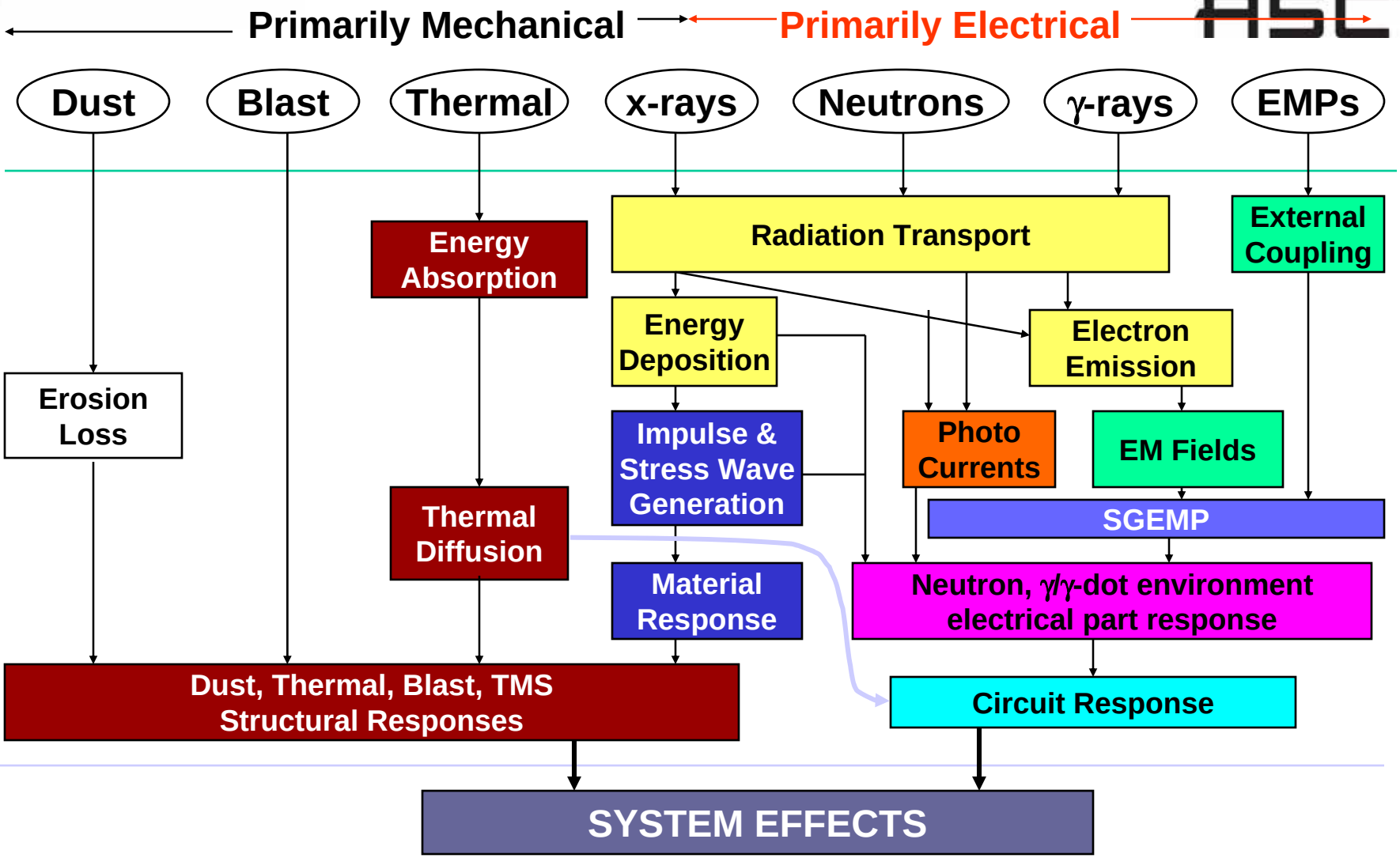
Nuclear detonations produce neutrons, gamma rays, and x rays.

Other source of radiation:

- Intrinsic
- Space
  - Electrons, Ions
- Radiography

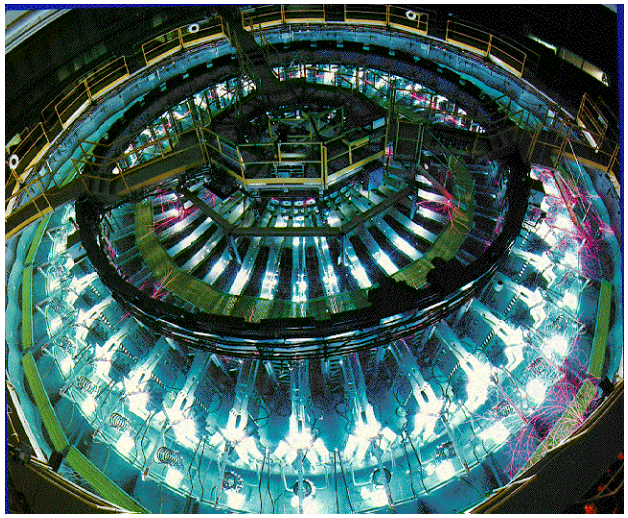
Sandia National Laboratories

Radiation Effects from Nuclear Detonation: Multiple Physics

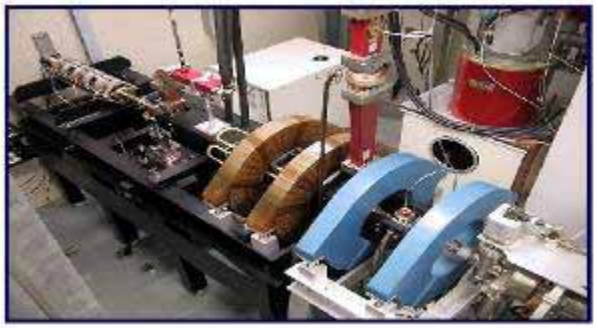


Sandia National Laboratories

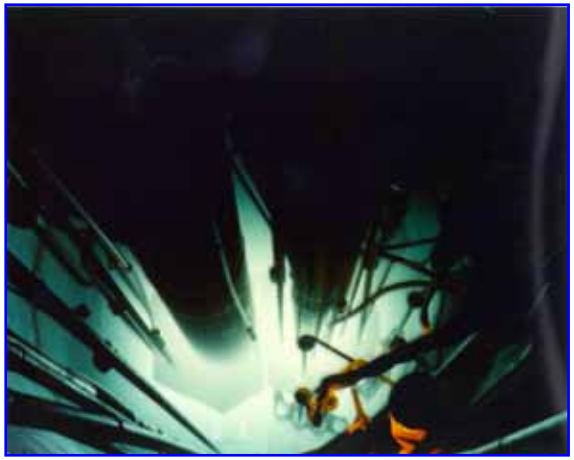
Radiation Generating Facilities Code Validation



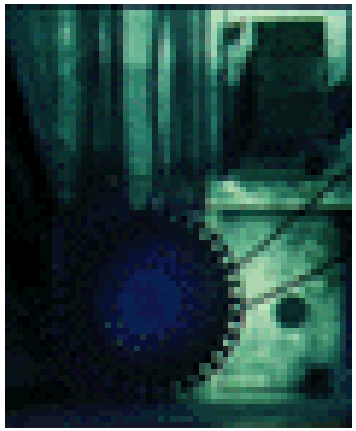
Bremsstrahlung
x-rays



Linear Electron Accelerator

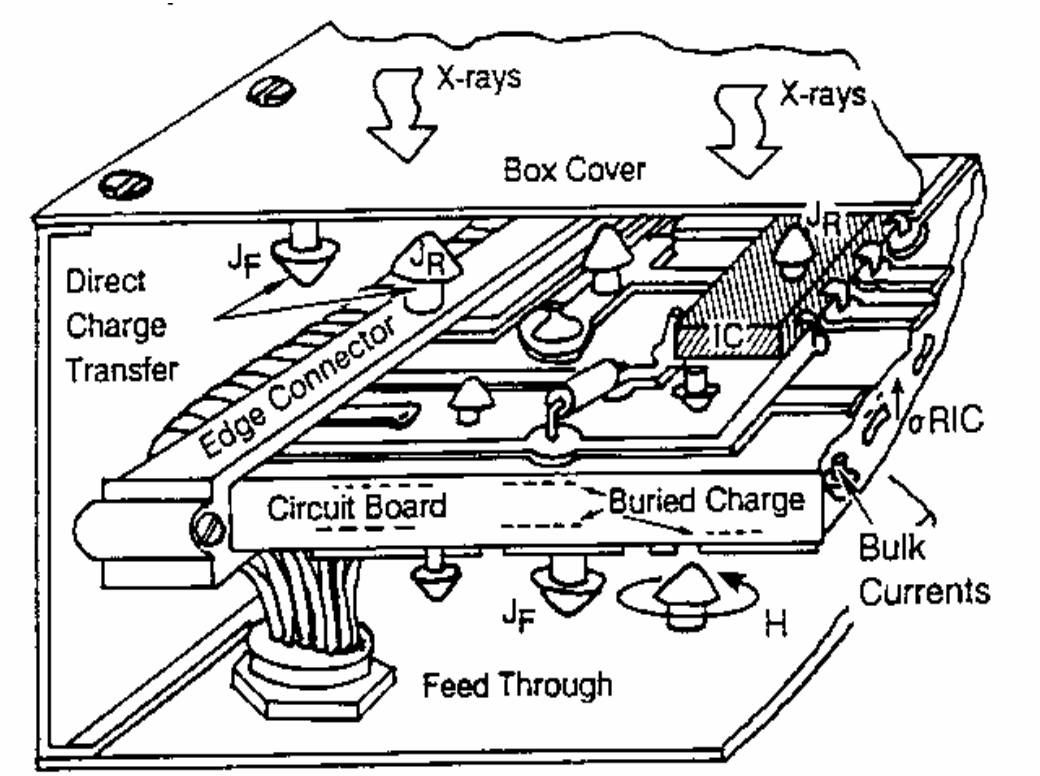


Neutron-gamma:
Reactor environments,
Co-60 Hot Cells

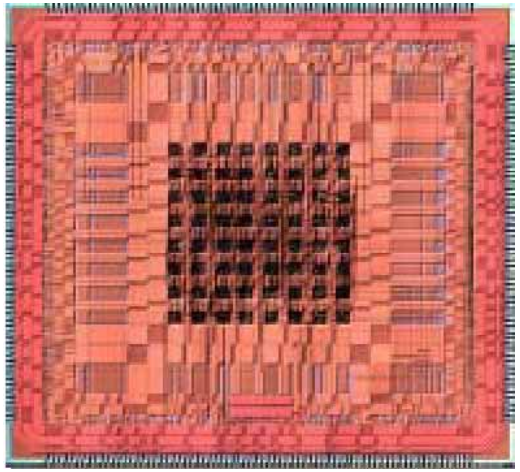


Sandia National Laboratories

Electrical Radiation Effects



Courtesy of Burr Passenheim, "How to do Radiation Tests"



Response of an
ASIC under radiation

System-Generated Electromagnetic
Pulse (SGEMP) Effects in Electronics

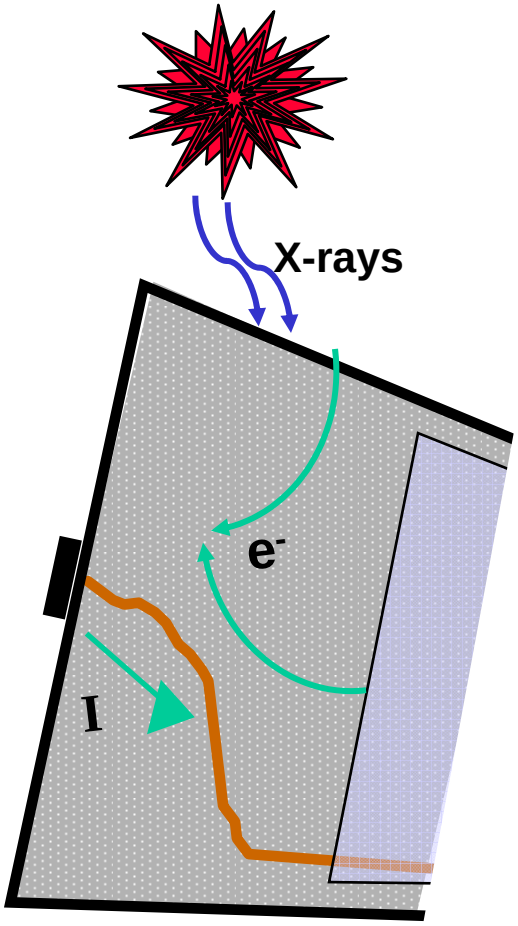
Sandia National Laboratories

Electrical Radiation Effects Physics Issues

- Better physics models are needed for codes to predict aging, especially under extended irradiation (from decay of fissile material)
  - Bipolar transistors exhibit enhanced low dose rate sensitivity (ELDRS): degradation of device performance at the lower, operational dose rates

- Better plasma physics of partially ionized gas mixtures at intermediate pressures for electromagnetics codes to simulate SGEMP in cavities

Cavity SGEMP code: EM fields with plasmas with coupled electron/photon transport "source"



Physical Processes:

- Photo-emission (time, energy, angle) from cavity surfaces
- Relativistic electrons present
- Electron-produced secondary emission
- Electron/photon-produced gas ionization
- Charge deposition in dielectrics
- Charge motion drives EM fields in cavity
- Fields drive currents on wires, cables shields, connectors
- Current penetrates into electrical components

EM Fields & Plasma Treatment Required:

- Fields and plasma currents are consistent per Maxwell's equations
- Energetic electron transport and "interactions" with gas and metals
- Ionized gas across vacuum to 1 atm pressure range

Radiation Transport:

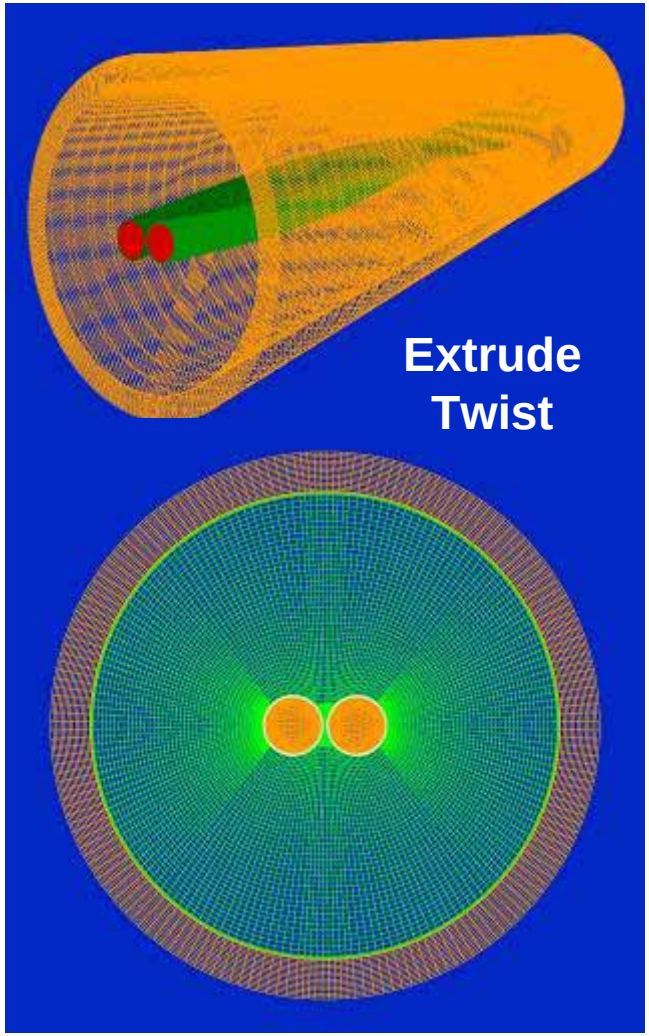
- Defines photo-emission
- Defines photon-induced gas ionization

Sandia National Laboratories

Particle Radiation Transport Electrical Effects

Research Areas:

- Efficient hybrid techniques that are optimized for coupled transport of particles that have radically different scale lengths (e.g. x-rays and electrons)
- Efficient deterministic transport methods on massively parallel computers for very large mesh (> 100 M elements)



Mesh of Cable

Sandia National Laboratories

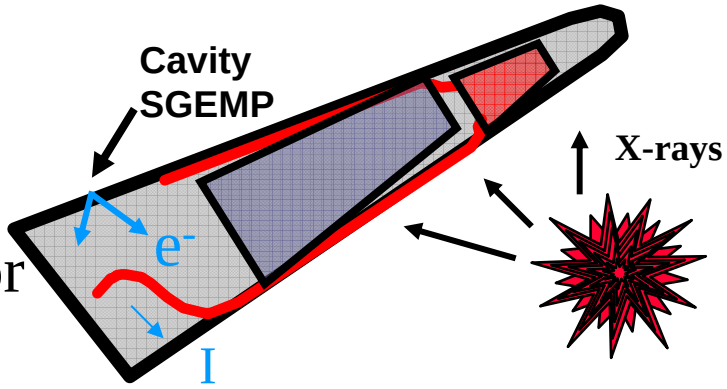
Particle Radiation Transport Other Needs

Research Areas:

- Efficient hybrid techniques for problems that are non-ideal for either Monte Carlo or deterministic
- Automatic biasing for Monte Carlo for deep penetration and/or secondary particle production
- Efficient utilization of engineering CAD models in Monte Carlo transport

Physics Models:

- Improved electron cross sections from 100 eV to 10 keV
- Validated electron transport models for small feature size



SGEMP prediction requires modeling the photoemission from extended surfaces, resolved in energy, angle and position.

Sandia National Laboratories

Material Radiation Effects Physics Issues

Better physics models are needed for computation:

- Polymer decomposition in weapons under extreme conditions, particularly after exposure to long-term low-level gammas and neutrons
- Fissile material morphological changes in high radiation environments
- Reactive plasma interactions with particulates and surfaces
- Electronic radiation-effects produced by high-energy, heavy ions

Material Radiation Effects Issues Possible Approaches

- Develop understanding of rate controlling processes for different radiation exposures and other stress factors as complex set of nonlinear processes control decomposition, composite materials add complexity, and common experimental methods do not provide sufficient information;
- Create mathematical models of processes since standard chemical kinetics analysis methods are insufficient.
- Develop decomposition kinetics and gas generation models and equations of state;
- Improve understanding of fundamental decomposition chemistry, and *ab initio* quantum chemistry calculations of transition states;
- Develop methods to rapidly postulate and test hypothetical models, in particular for transport and structural integrity model and computation of material response; and
- *Perform validation experiments.*

Radiation physics issues for new technology: MEMS

- These devices can be degraded by radiation damage.
- The radiation effects themselves also consist of a variety of mechanisms including displacement damage, single event effects, and total ionizing dose.
- In some instances, the exposed system is intended for a significant lifetime within a mixed radiation field.

Radiation Effects POCs

- Len Lorence, SNL, ljloren@sandia.gov
  - Particle radiation transport, electromagnetics, radiation effects associated with nuclear detonation
- Sharif Heger, LANL, heger@lanl.gov
  - Material effects in polymers and fissile materials, MEMS
- Bill Wolfer, LLNL, wolfer1@llnl.gov
  - Material effects (electronic excitation)
    - Reactive plasma interactions with surfaces
    - Electronic Effects from High-Energy Heavy Ions